IN THE SPECIFICATION:

Please amend the specification as follows:

Please insert the following paragraph beginning at page 1, line 5, as follows:

-- This application is a divisional application of copending U.S. patent application number 09/533,377, filed March 22, 2000. --

Please substitute the paragraph beginning at page 1, line 4, with the following.

-- This invention relates to a projection exposure apparatus for semiconductor manufacture and, more particularly, to a projection exposure apparatus for semiconductor manufacture which is usable in a lithographic process for the production of semiconductor devices or liquid crystal display devices, for example. --

Please substitute the paragraph beginning at page 1, line 11, with the following.

-- The density of an integrated circuit is increasing, and thus, projection exposure apparatuses for semiconductor manufacture should have a very high resolving power for projection exposure of a wafer to a circuit pattern formed on a reticle. In projection optical systems of such projection exposure apparatuses, for ~~improvements~~ improvement of the resolution, the numerical aperture (NA) has been enlarged or light of shorter wavelengths ~~have~~ has been used. At present, with a projection exposure apparatus having a light source of a KrF excimer laser (λ = 248 nm) and NA of 0.6, a resolution of 0.18 micron is attainable. --

Please substitute the paragraph beginning at page 2, line 1, with the following.

-- For production of a high resolution projection optical system, it is necessary to perform precise adjustment after a projection optical system is assembled. More specifically, for a projection optical system, optical evaluations in regard to spherical aberration, ~~comma~~ coma, distortion, and exposure magnification, for example, should be done. While adjusting lens group spacings or eccentricities, the optical performance that satisfies predetermined specifications is pursued. Usually, the evaluation of optical performance is made by projecting and printing an image of a mask pattern upon a resist (photosensitive material) applied to a photosensitive substrate (wafer) and by observing, after development, a resist image formed thereon. --

Please substitute the paragraph beginning at page 3, line 14, with the following.

-- Conventional projection exposure apparatuses are not equipped with any effective means for measuring wavefront aberration of a projection optical system after the same is mounted on the projection exposure apparatus. The goal for re-adjustment for image performance is, therefore, unfixed, and usually, the operation is interrupted to suppress the change. --

Please substitute the paragraph beginning at page 6, line 9, with the following.

-- In a case where the exposure light source comprises an excimer laser, usually, the coherent length is about several ~~ten~~ tens of millimeters, whereas the total length of a projection optical system, which is the subject of measurement, is about 1,000 millimeters. For this reason, it is practically unable to provide a Fizeau type interferometer. In consideration of it, in this

embodiment, a light source separate from the exposure light source is used exclusively for an interferometer for measurement of the wavefront of the projection optical system. --

Please substitute the paragraph beginning at page 6, line 20, and ending on page 7, line 12, with the following.

-- Denoted in the drawing at 6 is the light source to be used exclusively with the interferometer. Since the exposure wavelength is 248 nm in this embodiment, a light beam of 248 nm, corresponding to a second harmonic of <u>an</u> Ar laser is used. The Ar laser beam goes via a mirror and then through a condenser system 7 and a pinhole 8. By means of a collimator lens 9, the laser beam is transformed into a parallel beam. The diameter of the pinhole 8 is set as approximately the same as an Airy disc determined by the numerical aperture of the collimator lens 9. Therefore, the light beam emitted from the pinhole 8 comprises a substantially idealistically spherical wave. Since the collimator lens 9 is designed and produced substantially free from aberration, it can be considered that the light emitted from the collimator lens 9 comprises an idealistically plane wave. In the structure of Figure 1, the light from the light source 1 may be guided to the pinhole 8 by use of a polarization plane preserving fiber. --

Please substitute the paragraph beginning at page 7, line 19, with the following.

-- Usually, steppers include a reticle-to-wafer aligning means which may comprise a TTR alignment scope for detecting the wafer position through the reticle, and such <u>an</u> alignment scope may be mounted on and held by a moving mechanism for moving the TTR alignment scope to a

desired position on the reticle. In this embodiment, such a TTR alignment scope is used also as the interferometer objective lens 12 described above. --

Please substitute the paragraph beginning at page 8, line 21, and ending on page 9, line 21, with the following.

-- On the other hand, the light beam passed through the objective lens 12 is imaged at the position 15, corresponding to the reticle pattern position, and then it is imaged again by the projection optical system 16 at a position 17 which is at the wafer side thereof. There is a spherical surface mirror 20 disposed on the stage 19, and the curvature radius of the spherical mirror 20 is made equal to the distance from the imaging position 17 of the projection optical system. Thus, the light reflected by the spherical mirror 20 is collected again at the imaging position 17 of the projection optical system, and it goes again through the projection optical system, the objective lens 12, the mirror 11 and the half mirror 10. The light then passes the condensing system 27, and it is directed to the light receiving surface of the CCD 28. Since the light beam passing through the projection optical system 16 ~~interfere~~ interferes with the reference beam as reflected by the final face of the objective lens 12 as described above, the wavefront of the projection optical system can be measured, on the basis of it. Thus, by analyzing the outputs of the CCD 28 in a work station 50, annexed to the exposure apparatus, wavefront aberration as well as various aberrations of the projection optical system 16 such as wavefront aberration and field curvature, for example, causing the wavefront aberration, can be measured. --

Please substitute the paragraph beginning at page 9, line 22, and ending on page 10, line 7, with the following.

-- The spherical mirror 20 comprises a concave surface mirror in this example. However, a spherical mirror having a convex surface mirror may be used to provide an interferometer system. ~~In~~ On that occasion, the curvature center position of the convex surface mirror should be registered with the imaging position 17, and the mirror should be placed at an opposite side as compared with the concave surface mirror. As a further alternative, a plane surface mirror (or a wafer surface in substitution therefor) may be used. ~~In~~ On that occasion, with vertex reflection, only a revolutionally symmetrical component of wavefront aberration can be detected. --

Please substitute the paragraph beginning at page 11, line 5, with the following.

-- From the measurement of the wavefront of the projection optical system, information regarding the wavefront aberration at a measurement point is obtainable. Further, a revolutionally symmetrical component and a revolutionally asymmetrical component of the wavefront aberration as obtained through the measurement of the wavefront of the projection optical system 16 as well as the X-Y-Z coordinates of the objective lens 12 and the spherical mirror 20 as obtained from a measuring device during the wavefront measurement may be combined with each other, by which interrelationship among the measurement points of the projection optical system, can be determined. --

Please substitute the paragraph beginning at page 13, line 4, with the following.

-- Figure 2 is a schematic view of a second embodiment of the present invention. Like the first embodiment, in this embodiment, the invention is applied to an excimer laser stepper having an exposure wavelength of 248 nm. In this embodiment, a Twyman-Green type interferometer is provided on the reticle side. --

Please substitute the paragraph beginning at page 13, line 11, with the following.

-- Denoted at 6 is a light source for the interferometer, from which a light beam of 248 nm corresponding to the second harmonic of an Ar laser is extracted. The laser beam goes via a mirror, a condensing system 7 and a pinhole 8. Through an optical system 9, it is transformed into a parallel beam. The parallel light beam is then divided by a half mirror 10 into two light beams. The light beam passing through the half mirror 10 is reflected by a mirror 29 as a reference beam, and the reflected light beam is then reflected by the half mirror 10. After being reflected, the light beam passes through a condensing system 27 and it impinges on a light receiving surface of a CCD 28. --

Please substitute the paragraph beginning at page 13, line 25, and ending on page 14, line 19, with the following.

-- On the other hand, the light beam reflected by the half mirror 10 goes via a mirror 11, and it enters an objective lens 13. The light beam passing through the objective lens 13 is once imaged at a position 15 corresponding to the reticle pattern position, and then it is re-imaged by the projection optical system 16 at a position 17 on the wafer side. There is a stage 19 on which a spherical surface mirror 20 is mounted. The mirror has a curvature radius which corresponds to

the distance from the imaging position 17 of the projection optical system. Thus, the light reflected by the spherical mirror 20 is collected again at the imaging position of the projection optical system. Then, it goes back through the projection optical system 16 and passes via the objective lens 13, the mirror 11, the half mirror 10 and the condensing system 27. Finally, it impinges on the light receiving surface of the CCD 28. The light beam passing through the projection optical system 16 ~~interfere~~ interferes with the reference beam described above, such that the wavefront of the projection optical system can be measured. --

Please substitute the paragraph beginning at page 14, line 20, and ending on page 15, line 3, with the following.

-- ~~The~~ For the correction of a system error in the measured wavefront, use of a fringe scan method for enhancement of measurement precision, use of a spherical mirror of a convex surface mirror type, and calculation of aberrations of the projection optical system may be done in a similar way as in the first embodiment. On the basis of the results of these measurements, a predetermined lens or lenses of the projection optical system 16 may be displaced, by which the aberrations of the projection optical system can be adjusted and controlled into a desired state. --

Please substitute the paragraph beginning at page 15, line 10, and ending on page 16, line 6, with the following.

-- Denoted at 6 is a light source for the interferometer, from which a light beam of 248 nm corresponding to the second harmonic of an Ar laser is extracted. The laser beam goes via a mirror, a condensing system 7 and a pinhole 8. Through an optical system 9, it is transformed

into a parallel beam. The parallel light beam is then reflected by a half mirror 10, and it is directed via a mirror 11 to an objective lens 13. The light beam passing through the object lens 13 is imaged at a position 15 corresponding to the reticle pattern position, and then it is imaged again by the projection optical system 16 at a position 17 on the wafer side. There is a stage 19 on which a spherical surface mirror 20 is mounted. The spherical mirror 20 has a curvature radius which corresponds to the distance from the imaging position 17 of the projection optical system. Thus, the light reflected by the spherical mirror 20 is collected again at the imaging position 17 of the projection optical system, and it goes back through the projection optical system. Then, it advances via the objective lens 13, the mirror 11 and the half mirror 10, and it is introduced into an interferometer having components denoted by numerals 21-28. --

Please substitute the paragraph beginning at page 17, line 3, with the following.

-- ~~The~~ For the correction of a system error in the measured wavefront, use of a fringe scan method for enhancement of measurement precision, use of a spherical mirror of convex surface mirror type, and calculation of aberrations of the projection optical system may be done in a similar way as in the first embodiment. On the basis of the results of these measurements, a predetermined lens or lenses of the projection optical system 16 may be displaced, by which the aberrations of the projection optical system can be adjusted and controlled into a desired state. --

Please substitute the paragraph beginning at page 17, line 20, and ending on page 18, line 8, with the following.

-- Denoted at 6 is a light source for the interferometer, from which a light beam of 248 nm corresponding to the second harmonic of an Ar laser is extracted. The laser beam goes via a mirror, a condensing system 7 and pinhole 8. Through an optical system 9, it is transformed into a parallel beam. The parallel light beam then goes via a half mirror 10 and a mirror 11, and it enters an objective lens 32. The curvature radius of the final face of the objective lens 32 on the wafer side is made equal to the distance to an imaging plane 17 of the projection optical system 16 on its wafer side. Thus, reflection light from that final face is directed, as a reference light, to a light receiving surface of a CCD 28 via a mirror 31, the half mirror 10 and a condensing system 27. --

Please substitute the paragraph beginning at page 19, line 5, with the following.

-- Since the detection optical system is provided on the wafer side, by using the movability of the wafer stage in the X and Y directions, measurement can be done with respect to plural points within the picture plane of the exposure region. Thus, with the movement of the wafer stage, the spherical mirror 33 on the reticle side can be moved by the stage 34 to a predetermined position. Therefore, in addition to the wavefront measurement with respect to the individual measurement points, various wavefront aberrations such as distortion and field curvature, for example, of the projection optical system can be detected, by calculation, from the measurement data obtained in relation to the plural points. --

Please substitute the paragraph beginning at page 19, line 19, and ending on page 20, line 9, with the following.

-- ~~The~~ For the correction of a system error in the measured wavefront, use of a fringe scan method for enhancement of measurement precision, and calculation of aberrations of the projection optical system may be done in a similar way as in the first embodiment. Also, a modification of using a spherical mirror of a convex surface mirror type on the reticle side, may be made easily. However, in the case of this embodiment, the fringe scan can be accomplished by actuating a PZT device inside the reticle side stage 34 to shift the mirror 33 in the optical axis direction by an amount of about the wavelength, to cause phase modification of the wavefront. Alternatively, the fringe scan may be accomplished by actuating a PZT device inside the wafer stage 19 to move the objective lens 32 in the optical axis direction by an amount of about the wavelength, to cause phase modulation of the wavefront. --

Please substitute the paragraph beginning at page 20, line 10, with the following.

-- On the basis of the results of the measurements, a predetermined lens or lenses of the projection optical system 16 may be displaced, by which the aberrations of the projection optical system can be adjusted and controlled into a desired state. --

Please substitute the paragraph beginning at page 20, line 21, and ending on page 21, line 6, with the following.

-- Denoted at 6 is a light source for the interferometer, from which a light beam of 248 nm corresponding to the second harmonic of an Ar laser is extracted. The laser beam goes via a mirror 11 and enters an objective lens 13. The light beam passing through the objective lens 13 is imaged at a position 17 corresponding to the wafer position, and then it is imaged again by the

projection optical system 16 at a position 15 on the reticle side. The light thus imaged at the position 15 ~~is~~ advances via the objective lens 13, the mirror 11 and a half mirror 10, and it is introduced into an interferometer having components denoted by numerals 21-28. --

Please substitute the paragraph beginning at page 22, line 3, with the following.

-- The correction of a system error in the measured wavefront as well as calculation of aberrations of the projection optical system, for example, may be done in a similar way as in the first embodiment. On the basis of the results of these measurements, a predetermined lens or lenses of the projection optical system 16 may be displaced, by which the aberrations of the projection optical system can be adjusted and controlled into a desire state. --

Please substitute the paragraph beginning at page 22, line 12, with the following.

-- In a case of an i-line stepper, a basic wave of an argon laser ~~of~~ having a wavelength of 363.8 nm may be used. --

Please substitute the paragraph beginning at page 22, line 23, and ending on page 23, line 2, with the following.

-- Executing the measurement of an optical characteristic of a projection optical system, on the main assembly of a projection exposure apparatus, enables checking the state of the projection optical system as the same is there. It is, therefore, possible to take any necessary measures in accordance with the state of the projection optical system. --

Please substitute the paragraph beginning at page 23, line 3, with the following.

-- More specifically, as an example, the aberration state of the projection optical system can be corrected in accordance with the result of the measurement, or a judgment as to whether the operation should be interrupted or not can be made promptly. As a result of it, the exposure process can be performed with the imaging performance of the projection exposure apparatus held at a high level. This provides a large advantage in the production of semiconductor devices. --